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(54) Title: METHOD AND APPARATUS FOR PREDICTING SIGNAL CHARACTERISTICS IN A WIRELESS COMMUNICATION SYSTEM

(57) Abstract

The apparatus includes a memory (50) for storing representations of a micro-cellular transmitter (34) and a macrocellular transmitter (312). The representation of the microcellular transmitter is configured to transmit a representation of a first signal, the representation of the macrocellular transmitter is configured to transmit a representation of a second signal. A database (51) is responsive to the memory. The database has a plurality of data structures, and the plurality of data structures comprise a map of a geographic area. A predetermined location (11) is positioned on the map. A facet (600) having a size and comprising at least three points defining a plane is associated with the predetermined location. First (53) and second (54) instruction sets are available to calculate a characteristic of the first and second signals. A processor (52) responsive to the memory and the database uses one of the first instruction set and the second instruction set to calculate the characteristic at the predetermined location.

502 — LOAD AND INITIALIZE DATA
504 — SELECT LOCATION AND SIGNAL CHARACTERISTIC OF INTEREST
506 — DEFINE ENVIORMENTAL MODEL
508 — PROVIDE PREDICTION TECHNIQUES
510 — BEGIN PREDICTION PROCESS
512 — DETERMINE RESOLUTION AT WHICH SELECTED SIGNAL CHARACTERISTICS ARE CALCULATED
514 — DETERMINE FACET SIZE, PHYSICAL CHARACTERISTICS AND/OR LOCATION
516 — BASED ON FACET SIZE, PHYSICAL CHARACTERISTICS AND/OR LOCATION, SELECT A PREDICTION TECHNIQUE
518 — PREDICT SIGNAL CHARACTERISTICS
520 — MODIFY A PARAMETER OF THE SYSTEM

METHOD AND APPARATUS FOR PREDICTING SIGNAL CHARACTERISTICS IN A WIRELESS COMMUNICATION SYSTEM

Field of the Invention

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This invention relates generally to communication systems, and, more particularly, to a method and apparatus for predicting signal characteristics in a wireless communication system.

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Background of the Invention

Microcells, which are usually small, low-power radio base stations having small coverage areas, may be used to provide wireless communications in localized areas. Microcells may be coupled to larger base stations, or macrocells, through digital radio transmission or optical fibers. A typical cell site, either a microcell or a macrocell, includes one or more transceivers and a transmitter such as an antenna, and supplies communication services to subscribers within a designated coverage area of the cell site.

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Designing a communication system which includes both microcells and macrocells requires selecting geographic locations of transmitters, their desired coverage areas and their signal radiation patterns, so that specific frequencies, such as radio frequencies (RFs), are present within each cell's designated coverage area, while interference with other coverage areas sharing the same or similar frequencies is minimized.

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Prediction of actual signal propagation patterns into and out of cells may be difficult, however, because buildings and other terrain irregularities may reflect

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signals in unanticipated directions, resulting in
insufficient signal
strength in a one cell's designated coverage area and/or
unacceptable levels of interference in another cell's
5   coverage area.

     Several software tools are available which predict
signal propagation paths and aid in planning the
physical layout of a wireless communication system.
Examples of such tools include, but are not limited to,
10   Motorola's Netplan™ RF system planning and management
tool, Mobile Systems, Inc.'s PlaNet™ RF coverage tool,
LNS's RF planning tool and a commercially available
raytracing tool developed by T. Rappaport. Currently,
however, these and other software tools may not be
15   suitable for use in planning all types of communication
systems.

     First, environmental models or high-resolution maps
which model, typically via information stored in a
database, areas of interest within a geographic area
20   associated with the communication system and are used to
predict signal characteristics at a particular location
are different for macrocells than for microcells. For
example, macrocellular maps typically require less
resolution (or variable layers of resolution) than
25   microcellular maps, which typically are modeled using
high resolution databases.

     Second, simplistic pathloss equations and
empirical, or statistical, propagation models, are
generally used in connection with predicting signal
30   characteristics, such as signal strength, associated
with macrocells; while for microcells more sophisticated
ray tracing techniques, or deterministic models, are
used to predict signal characteristics such as actual
signal propagation paths. In general, databases
35   associated with macrocellular propagation models are in
different coordinate systems and/or formats than

databases associated with micorcellular propagation
models.

Although possible, it may be time consuming and
expensive to manually select and field test different
5   combinations of frequencies, signal radiation patterns
and/or signal powers to obtain complete coverage and
acceptable interference levels for each cell in a
communication system which includes both microcells and
macrocells.

10   There is therefore a need for a method and
apparatus for predicting signal characteristics in a
communication system having both microcells and
macrocells which integrates maps having different
resolutions into a single map having a single coordinate
15   system, and which adaptively adjusts the prediction of
signal characteristics based on the location of a
particular point of interest.

Summary of the Invention

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According to an aspect of the present invention,
the foregoing need is addressed by a method for
predicting a characteristic of first and second signals
at a predetermined location within a geographic area,
25   which operates in a wireless communication system
serving the geographic area, the wireless communication
system including the first transmitter and he second
transmitter, the first transmitter a microcellular
transmitter configured to transmit a first signal having
30   a first wavelength and the second transmitter a
macrocellular transmitter configured to transmit a
second signal having a second wavelength. The method
includes positioning representations of the first and
second transmitters; defining an environmental model of
35   the geographic area; defining a plurality of facets
within the environmental model, each of the plurality of

facets comprising at least three points defining a plane
and having a size, at least one facet associated with
the predetermined location; providing a first technique
for predicting the characteristic; providing a second
5   technique for predicting the characteristic; based on
the size of the at least one facet associated with the
predetermined location, on the first wavelength and the
second wavelength, using one of the first technique and
the second technique to predict the characteristic at
10   the predetermined location; and based on the prediction,
modifying a parameter associated with the wireless
communication system.

      According to another aspect of the present
invention, in a wireless communication system serving a
15   geographic area, an apparatus for calculating a
characteristic of a first signal and a second signal at
a predetermined location within the geographic area
includes a memory for storing representations of a
microcellular transmitter and a macrocellular
20   transmitter. The representation of the microcellular
transmitter is configured to transmit a representation
of the first signal and the representation of the
macrocellular transmitter is configured to transmit a
representation of the second signal. A database is
25   responsive to the memory. The database has a plurality
of data structures, and the plurality of data structures
comprise a map of the geographic area. The
predetermined location is positioned on the map. A
facet is associated with the predetermined location.
30   The facet has a size and comprises at least three points
defining a plane. A first instruction set for
calculating the characteristic and a second instruction
set for calculating the characteristic are provided. A
processor is responsive to the memory and the database,
35   and the processor uses one of the first instruction set

and the second instruction set to calculate the characteristic at the predetermined location.

According to a further aspect of the present invention, in a wireless communication system serving a
5   geographic area, the wireless communication system including a first transmitter and a second transmitter, the first transmitter a microcellular transmitter configured to transmit a first signal and the second transmitter a macrocellular transmitter configured to
10   transmit a second signal, an apparatus for determining a characteristic of the first and second signals at a predetermined location within the geographic area includes means for positioning representations of the first and second transmitters; means for defining an
15   environmental model of the geographic area; means for defining a plurality of facets within the environmental model, each of the plurality of facets comprising at least three points defining a plane and having a size, at least one facet associated with the predetermined
20   location; first means for predicting the characteristic; second means for predicting the characteristic; and means for selecting one of the first means for predicting and the second means for predicting to determine the characteristic at the predetermined
25   location, the selection based on the size of the at least one facet associated with the predetermined location and based on a wavelength of the first and second signals.

Advantages of the present invention will become
30   readily apparent to those skilled in the art from the following description of the preferred embodiment(s) of the invention which have been shown and described by way of illustration. As will be realized, the invention is capable of other and different embodiments, and its
35   details are capable of modifications in various respects. Accordingly, the drawings and description are

to be regarded as illustrative in nature, and not as restrictive.

Brief Description of the Drawings

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FIG. 1 is a diagram of a typical cellular communication system including both macrocells and microcells.

10   FIG. 2 is a flowchart of a method for predicting signal characteristics according to a preferred embodiment of the present invention.

FIG. 3 is a top view of an environmental model
15   which illustrates how buildings and other terrain irregularities may reflect antennae beam patterns in various directions.

FIG. 4 is a graphical representation of a facet
20   which may represent a portion of the environmental model shown in FIG. 3.

FIG. 5 is a block diagram of an apparatus for predicting signal characteristics in accordance with a
25   preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiments

Turning now to the drawings, wherein like numerals
30   designate like components, FIG. 1 is a diagram of a typical cellular communication system **200**. A number of mobile communication units (not shown), or mobile stations, may operate in areas **412**, **414** or **416** served by base stations **312, 314** and **316**, respectively. Base
35   stations **314** and **316**, along with corresponding areas **414** and **416**, respectively, are microcells, while base

station **312** and corresponding area **412** is a macrocell. Collectively, service areas **412, 414** and **416** cover a particular geographic area **400**.

A number of points **11**, or measurable regions, which may in fact represent areas of particular sizes or centers of specified areas in space, are shown within geographic area **400**. Points **11** may be located anywhere within area **400**. Any number of points **11** may be identified within area **400**, and it may be assumed that mobile stations operate at points **11**. Neighboring service areas **412, 414** and **416** may be overlapping (as shown) or substantially adjacent to each other. It is contemplated that base stations **312, 314** and **316** may be sectors of a sectored base station (not shown), or may themselves be sectored base stations, but in general are devices having transmitters such as antennae capable of emitting radio signals throughout an area over which communication is to be established. Wherever radio frequency channels are referred to herein, such channels are understood to refer to channels in code-based radio-frequency communication systems, as well as channels in frequency-based systems.

A base station such as base station **312, 314** or **316**, which is commercially available from Motorola, Inc., may include, among other things, a plurality of transceivers (not shown) which provide communication channels for communication between mobile communication units and base stations **312, 314** and **316**, and may also include a transmitter such as an antenna **19** which transmits and receives communication signals. Multiple frequencies, for example, multiple voice and signaling channels, may be transmitted from a single antenna **19**, using well-known combining methods. Antennae **19** may be any type, for example, directional-beam, uni-beam, omni-beam, patch or array, and its transmit power and/or

phasing may be controlled using various well-known techniques.

One or more of base stations **312**, **314** and **316** may be in communication with a base station controller (not

5   shown), such as a Motorola base station controller, having a well-known structure and function, or may itself be a complete base station system. Additional base stations may also be coupled to the base station controller, when present. The base station controller

10   or base station system may in turn be in communication with a switch (not shown), which may be a mobile switching center such as an EMX^{TM} 2500, commercially available from Motorola, or another suitable type of switch. Additional base station controllers (not shown)

15   or base station systems may also be coupled to the switch. The switch may be in further communication with, among other things, a public switched telephone network (PSTN) (not shown), allowing mobile communication units to access land-based communication

20   lines and vice versa.

Multiple access wireless communication between base stations **312**, **314** and **316** and mobile stations preferably occurs over radio frequency (RF) channels which provide physical paths over which communication

25   signals such as voice, data and video are transmitted. Base-to-mobile station communications are said to occur on a forward-link channel, while mobile-to-base station communications are referred to as being on a reverse-link channel. A communication channel may be, among

30   other things, a pilot channel, a paging channel, a synch channel, a traffic channel or part of a traffic channel.

When planning a wireless communication system such as system **200** depicted in FIG. 1, it is critical to properly select the geographic locations of base

35   stations **312**, **314** and **316** and the approximate boundaries of coverage areas **412**, **414** and **416** so that

suitable signals, such as radio frequency signals, propagate from antennae **19** to most every point in desired coverage areas **412**, **414** and **416** without causing undue interference in the form of adjacent channel or

5   cochannel interference. General considerations involved in designing a wireless communication system such as a cellular radiotelephone network are described in "The Communications Handbook," Jerry D. Gibson, Editor-in-Chief, CRC Press (1997), Chapter 81, pp. 1146-1159,

10   incorporated herein by reference.

     If characteristics of signals transmitted from antennae **19** can be accurately predicted, it is likely that base stations **312**, **314** and **316** will be properly located. As is well-known, signal characteristics, and

15   thus shapes and sizes of coverage areas **412, 414** and **416** may, in addition to being dependent on the location of buildings and other terrain irregularities, vary as a function of availability of sites to place antennae **19** and traffic congestion.

20   According to one aspect of the present invention, a method, a flowchart of which is illustrated in FIG. 2 (and further described with reference to FIG. 1 and other figures as necessary), provides for predicting signal characteristics in a wireless communication

25   system such as system **200** having both macrocells and microcells and mixed resolution databases, so that, among other things, desirable signal characteristics associated with each base station **312**, **314** and **316** exist at points **11**.

30   At block **502**, the step of loading and initializing data is performed. This step may include, among other things, representing base stations **312**, **314** and **316** in machine-readable format and selecting initial geographic locations of the representations of base stations **312,**

35   **314** and **316**, along with approximations of coverage areas **412, 414** and **416** based on different attenuation

levels. An initial set of transmit power values
associated with antennae **19** of base stations **312, 314**
and **316** and particular frequencies of signals
transmitted by antennae **19** may also be assumed. For
5   example, cellular radiotelephones currently operate in
the 890 MHz range and also in the 1.9 GHz range,
although other frequencies may be specified. If there
is an object in the near-field of a particular antenna,
then a library of antenna patterns may be used which has
10 been pre-generated using a numerical method such as
finite difference time domain (FDTD) or finite element
method (FEM).

The method continues at block **504**, where one or
more areas of interest, or a predetermined locations,
15 are selected. For example, one or more points **11** may
constitute an area of interest. One or more signal
characteristics of interest may also be selected at
block **504**. Examples of signal characteristics include,
but are not limited to, signal strength, signal
20 propagation path, signal interference and signal
polarization.

Next, at block **506**, an environmental model, or map,
of geographic area **200** is defined. An example of an
environmental model **300** is shown in FIG. 3. As shown,
25 objects which can redirect a propagating signal,
including but not limited to buildings **304, 306, 308**
and **310**, are located in relation to an antenna **19**,
which may be associated with one of base stations **312,**
314 or **316**. Location, size and composition of objects
30 such as buildings, terrain elevation and natural objects
such as trees, water and rocks may be modeled in three-
dimensions and stored in a database. Diffraction,
reflection and diffusion scattering coefficients in 3
dimensions of various objects such as known surfaces and
35 inhomogeneous rough surfaces are preferably developed
using numerical methods such as finite difference time

domain (FDTD) analysis or finite element analysis--
different materials are modeled with scattering
coefficients, which are in turn used to predict
characteristics of reflected or diffracted signals.

5   FDTD and/or other numerical methods may also be used to
develop realistic antenna patterns which include the
effects of walls, wedge shapes and corners when they
exist in the near field of an antenna. Certain
permitivities or dielectric properties of an object

10   being modeled may be assumed, and coefficients may be
extracted using a supercomputer. These coefficients may
then be stored, for future use, as data structures in a
database. For example the extracted coefficients may be
stored in a well-known format such as a lookup-table.

15   One approach to three-dimensional modeling is
described in "Integrated Macro and Microcellular
Propagation Model, Based on the Use of Photogrammetric
Terrain and Building Data," by E.K. Tameh et al., IEEE
(1997), pp. 1957-1961, incorporated by reference herein.

20   A propagation model for coverage prediction in the very
high frequency and ultra high frequency ranges which
considers uses a three-dimensional terrain data bank is
presented in "A Versatile Wave Propagation Model for the
VHF/UHF Range Considering Three-Dimensional Terrain," by

25   M. Lebherz et al., IEEE Transactions on Antennas and
Propagation, Vol. 40, No. 10, October 1992, pp. 1121-
1131, incorporated herein by reference. Other articles
concerning propagation and/or environmental models
include: "Two-Dimensional Ray-Tracing Modeling for

30   Propagation Prediction in Microcellular Environments,"
K. Rizik et al., IEEE Transactions on Vehicular
Technology, Vol. 46, No. 2, May 1997, pp. 508-517;
"Simulation of Radio Relay Link Performance Using a
Deterministic 3D Wave Propagation Model," by N. Geng et

35   al., Radio Relay Systems, C11-14 October 1993,
Conference Publication No. 386, IEEE, pp. 343-348;

Concepts and Results for 3D Digital Terrain-Based Wave
Propagation Models: An Overview," T. Kürner et al.,
IEEE Journal on Selected Areas in Communications, Vol.
11, No. 7, Sept. 1993; "Finite-Difference Time-Domain
5   Method for Electromagnetic Radiation, Interference, and
Interaction with Complex Structures," P.A. Tirkas et
al., IEEE Transactions on Electromagnetic Compatibility,
Vol. 35, No. 2, May 1993; "A Microcellular
Communications Propagation Model Based on the Uniform
10   Theory of Diffraction and Multiple Image Theory," S.Y.
Tan et al., IEEE Transactions on Antennas and
Propagation, Vol. 44, No. 10, October 1996; and "A Monte
Carlo FDTD Technique for Rough Surface Scattering," J.B.
Schneider et al., IEEE Transactions on Antennas and
15   Propagation, Vol. 43, No. 11, November 1995. Each of
these articles is incorporated herein by reference.
        Preferably, environmental model **300** accomodates
different resolutions for different regions within
geographic area **200**. For example, in a rural flat area
20   a resolution of 100-200 meters may be adequate, while a
10 meter or better resolution may be required in an
urban area or areas having irregular terrain. It is
desirable to achieve such a non-homogeneous map while
retaining a single coordinate system. Data collected
25   through various means such as satellite, maps and aerial
photographs, among other means, are generally
represented in an ellipsoid coordinate system or a
spherical coordinate system. It is preferable to
transform the ellipsoid coordinate system into a
30   rectangular coordinate system and to use only
rectangular (Cartesian) coordinate physics.
        Geographical data is preferably separated and
classified into rural, urban and mixed areas. Rural
areas are further classified based on land cover and
35   elevation. Examples of land cover include forests
(having a certain density of trees per area), lakes,

open dry lands and open wetlands. Examples of elevation include flat areas, flat areas having particular irregularities or roughness, hilly areas and mountainous terrain. Urban areas may be classified based on

5   building density, defined, for example, by typical U.S. cities, European cities and suburban areas. Each class of data may be assigned its own reflection coefficient and/or diffusion coefficient, and transition regions may also be defined.

10   At block **508**, prediction techniques are provided which simulate the redirection, that is, the reflection, diffraction or diffusion, of a signal **28** within environmental model **300**. A first technique for predicting a characteristic of signal **28** transmitted

15   from one or more antennae **19** is a deterministic technique, which includes the use of mathematical formulas, such as three-dimensional scattering calculations, which describe physical phenomena. The use of such calculations is commonly referred to as

20   raytracing. Typically, the underlying calculations are based on the uniform theory of diffraction or geometrical/physical optics, that include plane wave equations characteristics, described in the rectangular coordinate system.

25   According to a preferred embodiment of the present invention, energy radiated from an antenna is treated as energy density, i.e., watts per square meter. Such radiated energy hits an object such as a wall at a surface rather than at a point. As a result, currents

30   may be induced at the surface, which currents re-radiate. The nature of the surface (i.e., its material and geometry) determines the surface currents. A direction of the re-radiated energy, and information about the new signal characteristics (e.g., polarization

35   state, signal strength, signal amplitude), is detected. For example, a vertically-polarized signal may

depolarize after reflecting off of a dielectric or
inhomogeneous object. It is preferable to predict a
degree of polarization or depolarization based on a
library of facets (discussed further below), each of

5   which has a particular material composition and
inhomogenuity, so that when an incident signal strikes a
certain facet at a particular polarization, the
polarization state of the reflected signal may be known
or selected. Such a technique and/or library is

10 commonly referred to as a polarometric scattering
matrix.

A second technique for predicting the
     Alternatively, attenuation of a signal such as
signal 28 may be deterministically predicted using the
well-known method of images, or the well-known dot

15 product method. A detailed description of the method of
images may be found in U.S. Patent Applications Nos.
08/701,257, 08/656,029, 08/415,051 and 08/685,344,
commonly assigned with the present invention. Each of
the above-referenced U.S. Patent Applications is

20 incorporated herein by reference.

     A second technique for predicting the
characteristic of signal 28 is a statistical/empirical
technique, which preferably involves the use of
numerical methods. Examples of numerical methods

25 include FDTD, finite element methods (FEM) or the method
of moments (MOM). The results of the numerical methods
may be pre-calculated and stored in a library, database,
table or the like. For example, a library of
diffraction coefficients for different kinds of building

30 corners may be created and chosen by a user, or if there
is no detailed building information available,
diffraction coefficients associated with typical
inhomogeneous wedges may be selected. A scattering
matrix having row and/or elements such as Fresnel

35 coefficients may be used for three-dimensional type of
problems.

Next, at block **510**, a process begins which
automatically determines the signal characteristic(s) of
interest at the selected area(s) of interest.

At block **512**, it is shown that the size of the area

5   of interest selected determines the resolution at which
the selected signal characteristics are calculated. For
example, if the area of interest is ten meters square,
the rectangular coordinates of this area of interest are
identified. This area of interest may be broken down

10   into the smallest possible individual regions if a high
degree of resolution is desired, or may be treated as
one complete region if a lower degree of resolution is
desired. In general, smaller areas of interest will
provide a higher resolution output while larger areas of

15   interest will provide a lower resolution output.

Each area of interest is preferably represented by
one or more facets. A facet **600**, as shown in FIG. 4, is
a plane determined and bounded by three or more points
in three-dimensional space, and is an object well-known

20   in the field of computer science. Facet **600** may be
triangular or rectangular. A vector N **602** normal to the
plane of facet **600** is also shown. A single area of
interest may contain one or more facets of varying
sizes. A library of facets is preferably created, so

25   that each facet has a particular material composition
and inhomogenuity at a particular angle of incidence.

Facets **600** preferably vary in size according to the
resolution at which selected signal characteristics are
calculated and may also vary in size according to the

30   importance of the location of the facet. For example,
areas on or near major roads or buildings may be deemed
more important, and therefore have more and smaller
facets associated therewith, than unpopulated areas such
as fields or lakes. In addition, facets are preferably

35   sized based on geographical features such as land cover
and elevation, as discussed above. For example, in a

forested area facet size may be different (e.g., larger) than in an urban area. Each facet will have its own reflection coefficient and/or scattering diffusion coefficient.

5   According to the preferred embodiment of the present invention, a technique for predicting the selected signal characteristic at a particular area of interest is automatically, or adaptively, utilized based on the size of the facet or facets defining the

10   particular area of interest, relative to the frequency of the signal being studied. For example, it is well-known that if a signal has a wavelength which is equivalent or greater than the radius of a surface of a facet, the technique of geometrical optics may not

15   accurately predict characteristics of that signal. In that case, a numerical method technique such as FDTD may be used. Conversely, when a wavelength of a signal is much less than the size of a facet, the technique of geometrical optics may be successfully employed.

20   A technique for predicting the selected signal characteristic at a particular area may also be based upon the material defined by a particular facet or portion thereof, and/or a location of a particular facet. For example, various levels of irregularities of

25   a material or terrain may be defined, and for irregularities of a particular size, either deterministic models or statistical methods may be used to predict signal characteristics.

Thus, as shown in FIG. 2, the facet's size,

30   physical characteristics and location are determined at block **514** and a prediction technique is selected at block **516**.

The signal characteristic is predicted at block **518**. The result of the prediction may be displayed

35   graphically in three-dimensions, graphically in two-

dimensions, in table format or in any other suitable fashion.

Adapting the manner of predicting signal characteristics according signal frequency and according to facet size and material associated with the area of interest provides many benefits. For example, a single uniform coordinate system, and a single environmental model, may be used to predict the propagation of electromagnetic fields in environments associated with both macrocells and microcells--what is flat at 890 MHz may not appear flat at 1.9GHz.

As shown at block **520**, it may be desirable to modify a parameter associated with the wireless communication system based on the prediction of a signal characteristic. Examples of parameters which may be modified include, among other things, locations of base stations **312**, **314** and **316**, one or more transmit power values associated with antennae **19** of base stations **312, 314** and **316** and particular frequencies of signals transmitted by antennae **19**.

In this manner, it is possible to automatically predict signal characteristics at various points within geographic area **400** associated with wireless communication system **200**. Combinations of base station and/or antennae locations, frequencies and signal powers which most fully cover service areas **412, 414** and **416** with the least propagation into neighboring service areas at any given point **11** may be selected.

Referring to FIG. 5, and also to FIGs. 1-4 as appropriate, an apparatus **60**, which may be, for example, a general purpose computer, for predicting signal characteristics in accordance with a preferred embodiment of the present invention, is illustrated. A memory **50** stores information representing geographic locations of signal transmission sources such as base stations **312, 314** and **316** and types of antennae **19**

along with various transmission frequencies and/or powers. A database **51** responsive to memory **50** stores a number of data structures representing the environmental model, or map, of geographic area **400**. Data may be

5 represented in memory **50** and/or database **51** in a variety of well-known ways, for example, using mathematical expressions, data structures, digital representations or tables, for example. The environmental model may have a specific coordinate system (not shown), with individual

10 areas of the system having one or more facets **600** of varying sizes associated therewith. A predetermined space may be represented by three-dimensional facets of varying sizes using well-known computer science techniques.

15 A processor **52** is in communication with memory **50** and database **51**. Processor **52** may be responsive to a program (not shown), which may reside in memory **50** and which may be, for example, an instruction set written using well-known methods in a computer-readable

20 language, which executes the various aspects of the method described in connection with the preferred embodiment(s) of the present invention. For example, the method may be implemented in software, written in a language such as C and/or C++ and performed on a high-

25 performance workstation with one or more microprocessors using serial or parallel processing techniques. The program, in conjunction with processor **52**, memory **50** and database **51**, may, based on the size of the facet or facets defining a particular area of interest, utilize

30 either instruction set **53** or instruction set **54** to predict the selected signal characteristic at the particular area of interest.

Of course, apparatus **60** may include one or more other devices or elements, such as a keyboard (not

35 shown), a pointing device (not shown) a display device (not shown), or a network interface (not shown).

Memory **50**, processor **52** and its associated
program, database **51** and instruction sets **53** and **54** may
be components of, or implemented within, a simulation
tool such as Motorola's Netplan™ software tool.

5   Various aspects of the present invention pertain to
specific functions implementable on computer systems in
general. And a program implementing the specific
functions may be delivered to a computer in many forms,
including but not limited to permanent storage on a non-

10   writable storage medium, alterable storage on a writable
storage medium, or conveyed through communication media
such as a computer network, the public switched
telephone network, a fiber optic cable, or transmitted
radio frequency signals.

15   The principles of the present invention which apply
to cellular-based communication systems may also apply
to other types of communication systems, including but
not limited to personal communication systems, satellite
communication systems and data networks, and further

20   apply to cellular communication systems having any
number of cells. Likewise, the principles described
herein are applicable whether the communication systems
are analog or digital, one-directional or two-
directional. And it will be understood that a

25   communication system, and network elements therein, in
which the aspects of the present invention may be used,
may be configured in any suitable manner. The various
embodiments of the present invention may be used in
connection with communication signals having any

30   frequency and with communication systems following any
air interface standard.

It will be apparent that other and further forms of
the invention may be devised without departing from the
spirit and scope of the appended claims and their

35   equivalents, and it will be understood that this
invention is not to be limited in any manner to the

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specific embodiments described above, but will only be
governed by the following claims and their equivalents.

Claims

We claim:

5   1.   In a wireless communication system serving a
geographic area, the wireless communication system
including a first transmitter and a second transmitter,
the first transmitter a microcellular transmitter
configured to transmit a first signal having a first
10   wavelength and the second transmitter a macrocellular
transmitter configured to transmit a second signal
having a second wavelength, a method for predicting a
characteristic of the first and second signals at a
predetermined location within the geographic area, the
15   method comprising the steps of:
        positioning representations of the first and second
transmitters;
        defining an environmental model of the geographic
area;
20   defining a plurality of facets within the
environmental model, each of the plurality of facets
comprising at least three points defining a plane and
having a size, at least one facet associated with the
predetermined location;
25   providing a first technique for predicting the
characteristic;
        providing a second technique for predicting the
characteristic;
        based on the size of the at least one facet
30   associated with the predetermined location, the first
wavelength and the second wavelength, using one of the
first technique and the second technique to predict the
characteristic at the predetermined location; and
        based on the prediction, modifying a parameter
35   associated with the wireless communication system.

2.   The method according to claim 1, wherein the wireless communication system comprises a cellular radiotelephone communication system.

5   3.   The method according to claim 2, wherein the cellular radiotelephone communication system is selected from the group consisting of: a code division multiple access (CDMA) system, an analog system and a time division multiple access (TDMA) system.

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4.   The method according to claim 1, wherein the predetermined location comprises a three-dimensional area.

15   5.   The method according to claim 1, wherein the environmental model comprises a map.

6.   The method according to claim 5, wherein the map comprises a database.

20

7.   The method according to claim 6, wherein the database comprises representations of terrain data and representations of clutter data integrated into a single data set.

25

8.   The method according to claim 7, wherein the clutter data comprises three-dimensional buildings.
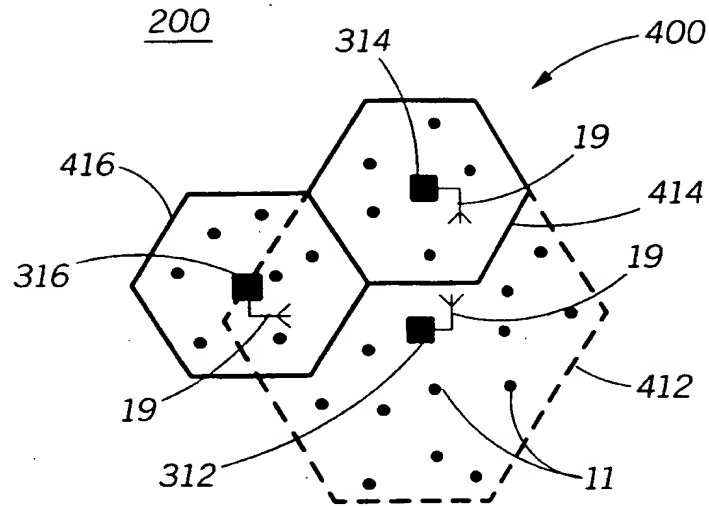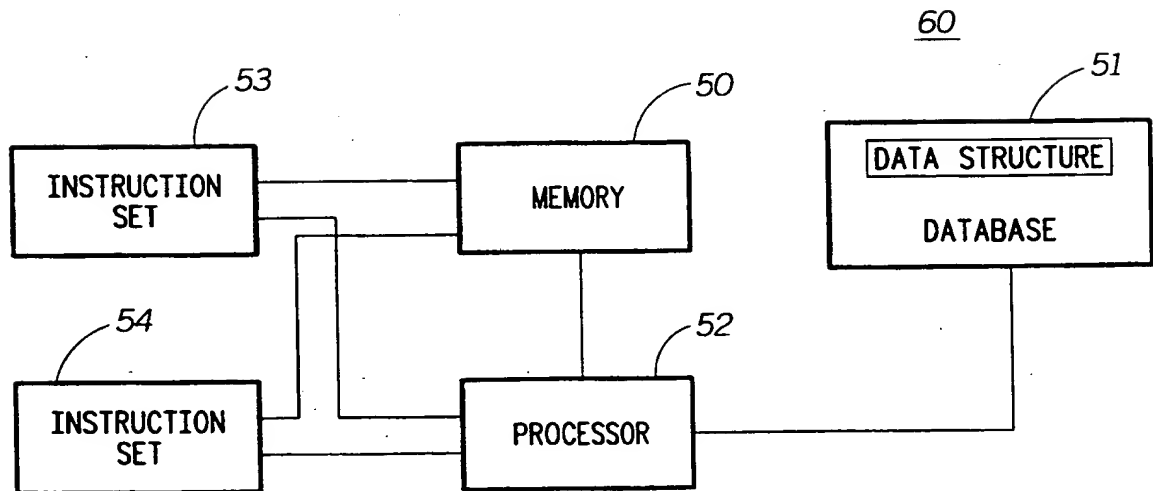
9.   The method according to claim 1, wherein each
30   of the plurality of facets further comprises a vector normal to the plane.

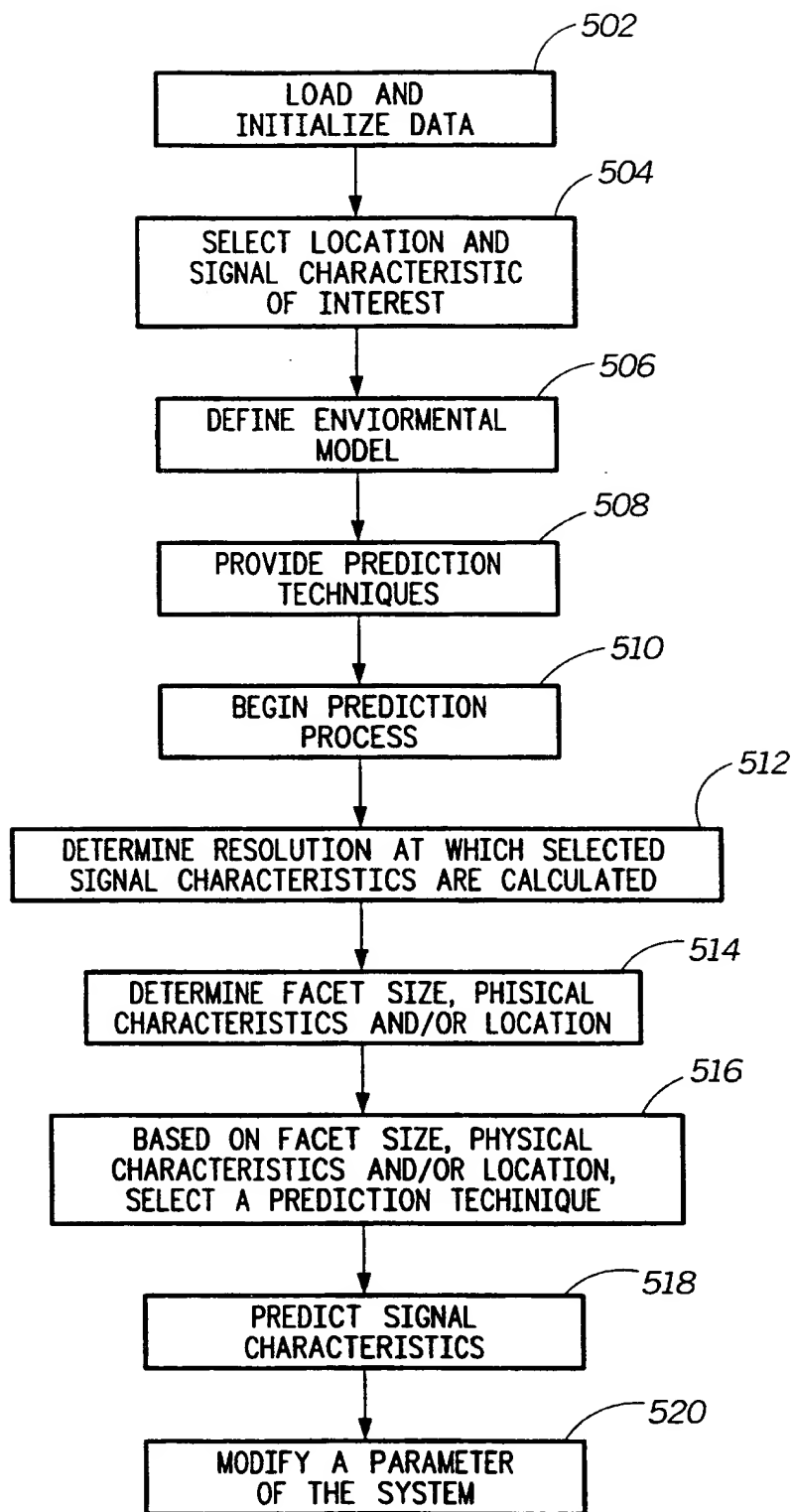10.   The method according to claim 1, further comprising the step of:
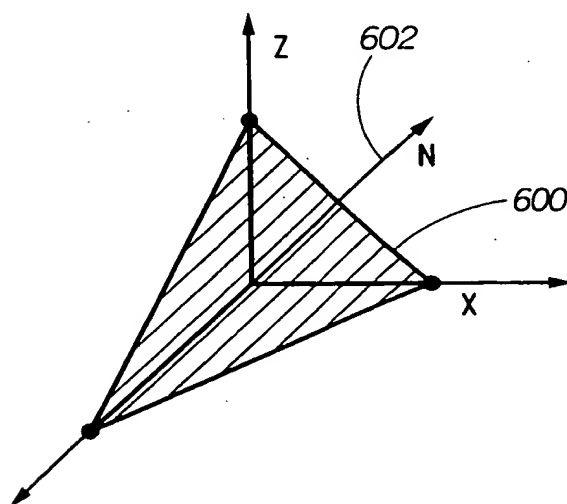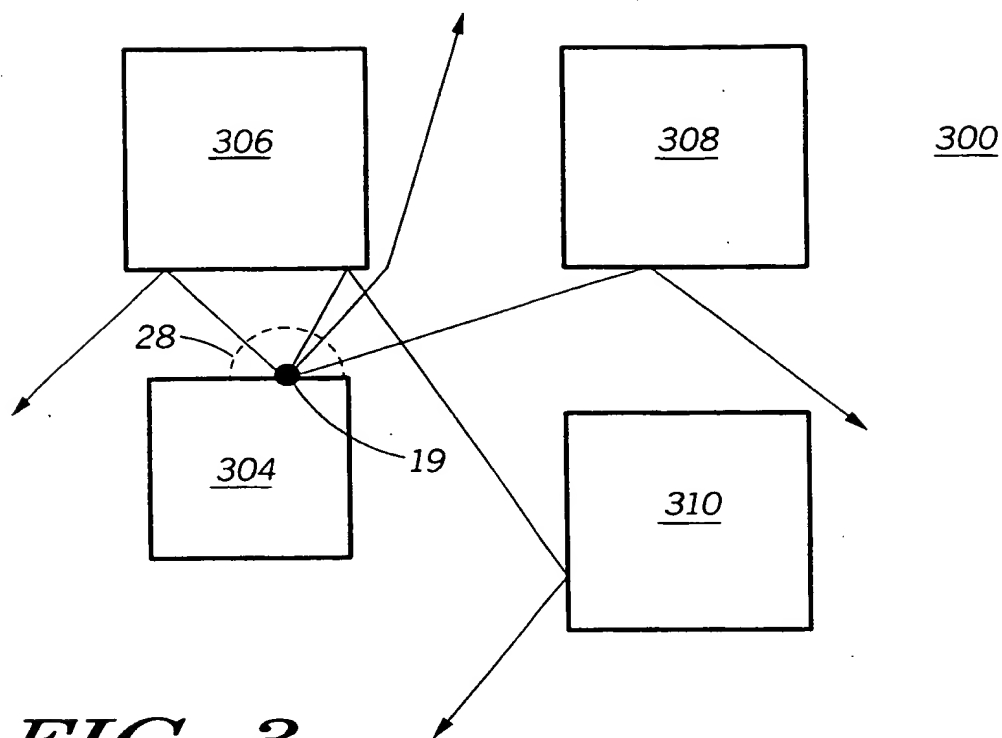35   assigning a priority value to each of the plurality of facets.

FIG. 1

FIG. 5

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            ┌──────────────────────┐  ╱ 502
            │     LOAD  AND        │
            │  INITIALIZE DATA     │
            └──────────────────────┘
                      │
                      ▼
            ┌──────────────────────┐  ╱ 504
            │  SELECT LOCATION AND │
            │  SIGNAL CHARACTERISTIC│
            │     OF  INTEREST     │
            └──────────────────────┘
                      │
                      ▼
            ┌──────────────────────┐  ╱ 506
            │  DEFINE ENVIORMENTAL │
            │        MODEL         │
            └──────────────────────┘
                      │
                      ▼
            ┌──────────────────────┐  ╱ 508
            │  PROVIDE  PREDICTION │
            │      TECHNIQUES      │
            └──────────────────────┘
                      │
                      ▼
            ┌──────────────────────┐  ╱ 510
            │  BEGIN  PREDICTION   │
            │       PROCESS        │
            └──────────────────────┘
                      │
                      ▼
    ┌──────────────────────────────────┐  ╱ 512
    │ DETERMINE  RESOLUTION  AT  WHICH  SELECTED │
    │  SIGNAL  CHARACTERISTICS  ARE  CALCULATED  │
    └──────────────────────────────────┘
                      │
                      ▼
    ┌──────────────────────────────────┐  ╱ 514
    │  DETERMINE  FACET  SIZE,  PHISICAL │
    │  CHARACTERISTICS  AND/OR  LOCATION │
    └──────────────────────────────────┘
                      │
                      ▼
    ┌──────────────────────────────────┐  ╱ 516
    │  BASED  ON  FACET  SIZE,  PHYSICAL │
    │  CHARACTERISTICS  AND/OR  LOCATION, │
    │  SELECT  A  PREDICTION  TECHINIQUE │
    └──────────────────────────────────┘
                      │
                      ▼
            ┌──────────────────────┐  ╱ 518
            │  PREDICT  SIGNAL     │
            │  CHARACTERISTICS     │
            └──────────────────────┘
                      │
                      ▼
            ┌──────────────────────┐  ╱ 520
            │  MODIFY  A  PARAMETER │
            │   OF  THE  SYSTEM    │
            └──────────────────────┘
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FIG. 2

FIG. 3

FIG. 4

International application No.

PCT/US98/17473

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6)   : H04B 17/02
US CL   :455/449, 524, 67.6
According to International Patent Classification (IPC) or to both national classification and IPC

B.   FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. :   455/446, 449, 524, 67.1, 67.3, 67.6, 422, 423, 40; 364/514

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,491,644 A (PICKERING et al.) 13 February 1996 (13.02.96), col. 5, line 6 through col. 6, line 39.	All
A	US 5,689,812 A (TAKAHASHI) 18 November 1997 (18.11.97), Fig.1.	All
A	US 5,561,841 A (MARKUS) 01 October 1996 (01.10.96), Fig. 1.	All
A	US 5,301,127 A (HITNEY) 05 April 1994 (05.04.94), abstract.	All
A	TAMEH et al. A 3-D INTEGRATED MACRO AND MICROCELLULAR PROPAGATION MODEL, BASED ON THE USE OF PHOTGRAMMETRIC TERRAIN AND BUILDING DATA, IEEE 1997, pp1957-1961.	All

☐ Further documents are listed in the continuation of Box C.   ☐   See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 OCTOBER 1998	03 DEC 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington. D.C. 20231	Authorized officer LESTER KINCAID. Dian Smith
Facsimile No. (703) 305-3230	Telephone No. (703) 306-3016

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